View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by CSCanada.net: E-Journals (Canadian Academy of Oriental and Occidental Culture,...

CSCanada
Management Science and Engineering
Vol. 11, No. 1, 2017, pp. 31-39
DOI:10.3968/9329

ISSN 1913-0341 [Print]
ISSN 1913-035X [Online]
www.cscanada.net
www.cscanada.org

A Decision-Making Model for Supplier Selection in Public Procurement

YU Jianjun[a],*; CAI Xiaofei[b]

[a]Associate Professor, School of Business Administration, South China University of Technology, Guangzhou, China.
[b]Master, School of Business Administration, South China University of Technology, Guangzhou, China.
*Corresponding author.

Received 12 November 2016; accepted 13 February 2017
Published online 20 March 2017

Abstract

Public procurement is a multi-criteria decision-making (MCDM) problem that meets lexicographic preference to some extent. In this paper, a two-layer method that meets lexicographic preference selection was proposed to address the government procurement decision-making problem of multi experts in the fuzzy environment. The decision-making process of this model is divided into two steps. Firstly, attributes of multiple experts were collected according to their rights of speech, getting the comprehensive attribute preference order. Secondly, the program meeting lexicographic preference was decided based on the comprehensive attributes. Finally, the proposed model was applied to the firefighting cushion bidding case of Fire Station of A public security department. Results demonstrated that the proposed model is applicable to public procurement decision-making and can provide effective references to decision-making on government procurement.

Key words: Lexicographic preference; Multi-criteria decision-making; Public procurement

Yu, J. J., & Cai, X. F. (2017). A Decision-Making Model for Supplier Selection in Public Procurement. *Management Science and Engineering*, *11*(1), 31-39. Available from: URL: http://www.cscanada.net/index.php/mse/article/view/9329
DOI: http://dx.doi.org/10.3968/9329

INTRODUCTION

With the perfection of administration transparency and government accounting disclosure system, government procurement becomes increasingly important in the whole society economy, politics, culture and ecology (Nicola et al., 2011). According to data on the government procurement information network, China accomplished RMB 20.67 billions of purchase in 2014 and saved RMB 4.127 billions, showing an average capital saving rate of 16.64%. *Enforcement Regulations on Government Procurement of the People's Republic of China* (No. 658) of China's Decree of the State Council made clear regulations on centralized purchasing of public procurement, online bidding of electronic trading as well as interest relationship between purchasing staff and related suppliers, which put forward higher requirements on disclosure, transparency, scientificity and high efficiency of supplier selection in China's government procurement. Existing research methods of multi-criteria decision making (MCDM) concerning supplier selection of public procurement mainly include:

(a) Intuitive judgment method

Intuitive judgment is a qualitative method for supplier selection according to data and individual analytical judgment. It is the main method for government procurement to choose suppliers in early stage. Supplier selection began to be studied and use qualitative-qualitative method since Harris put forward the economic order quantity (EOQ) in 1915.

(b) Linear weighting method

Gregory proposed the supplier selection based on classification in 1986 (Zegeret al., 2000). Subsequently, the supplier selection method through weighted combination of suppliers' attributes and attribute weights was widely applied (Zhang et al., 2001).

(c) Cost method

It was started from EOQ, mainly including purchase cost method and operation cost method. The former one is to compare purchase costs of suppliers under the premise of basic goal realization (Lin, 2000). The later one is a method to select suppliers by analyzing total cost of

Copyright © Canadian Research & Development Center of Sciences and Cultures

suppliers. It was proposed by Roodhooft and Jozaf (1996). The main principle of cost method is to make contrast selection of product suppliers according to direct cost (e.g. purchase and inventory costs) and indirect cost (e.g. quality and delivery time).

(d) Mathematical programming approach

It is a planning and management method to optimize the goal under limited conditions.

(e) Analytic hierarchy process (AHP)

In 1992, Nydick and Hill suggested to use AHP in supplier selection for the first time (Nydick, 1992). AHP is a decision-making method that determines the judgment matrix of pairwise method and uses the maximum feature of the judgment matrix as well as component of the corresponding feature vector as the coefficients (Lou & Chen, 2002). It can quantify qualitative factors in supplier selection indexes and is applicable to decision-making problem in the fuzzy environment. At present, AHP is widely used and studied. The two-layer AHP meeting lexicographic preference selection proposed in this paper not only introduces lexicographic preference into AHP according to supplier selection characteristics of public fields, but also meets MCDM analysis which combines multi-group opinions.

Additionally, there are ideal solution sorting method TOPSIS (Isiklar & Buyukozkan, 2007), elimination and selection conversion method ELECTRE (Almeida, 2007), preference order structure evaluation method PROMETHEE (Brans & Vincke,1985) and data envelopment method. Based on comprehensive analysis, existing researches on supplier selection of government procurement mainly constructs the government procurement index (attribute) system with public characteristics according to government characteristics and then applies the general MCDM approaches in public procurement. However, in current China's government procurement cases, the government procurement indexes are already relatively mature. Government determines explicit index (attribute) system according to the desired special commodity and services and discloses it before the official open tendering. Therefore, current researches reported that the supplier selection index system construction in public procurement is overvalued in researches on supplier selection of government procurement. Nevertheless, the follow-up supplier selection model according to the index system comes from private and enterprise purchase directly, without government procurement characteristics. According to characteristics of government procurement, a decision-making model meeting lexicographic preference in public procurement in the fuzzy environment was put forward, which emphasized on construction of supplier selection model of government procurement.

Lexicographic preference is a special preference for MCDM problem. Lexicographic preference in the decision process is a kind of deliberate or unintentional selection preference. As the name implies, lexicographical order is similar to looking up in the dictionary. Firstly, it compared the most important attributes. If different plans have different values, the better one shall be selected firstly. If different plans have the same values, the second most important attribute shall be considered and the previous step shall be repeated. For example, "ask" and "at" are decided according to importance in alphabet order. Firstly, the decision-making involves four attributes: *a*, *s*, *k* and *t*. The importance ordering of these four attributes according to the alphabet is *a*, *k*, *s* and *t* (importance descending). In the decision-making, the first thing is to decide importance of the attribute *a*. Both "ask" and "at" start with *a*. Then, the second attribute shall be considered. The second attributes of "ask" and "at" are *k* and Φ, respectively. Since Φ is prior to k, it can be decided that "at" is prior to "ask" (Jozsef & Nandor, 2005). The lowest bid evaluation method which is the most common method of government procurement is the lexicographic preference decision-making of partial attributes which uses price (purchase cost) as the most important attribute.

Government purchasing by invitation to bid has lexicographic preference compared to MCDM problem in general contexts, which is mainly because the government has certain characteristics as a non-profit public sector.

Firstly, limitations and responsibility requirements of government procurement decision-making are enhancing increasingly. The intensifying anti-corruption of China's government is conducive to perfection of people's supervision and hearing systems to the government day by day. Purchasing problems involving government finance are asked to be more scientific and transparent. Government purchasing by invitation to bid involves various complicated attributes in society, economy, politics and culture. These first-level attributes also have more sub-level attributes. Perfection and refining of the government procurement index system are the prerequisites for people's supervision. However, refined indexes increase complicity and workload of the decision-making process, which brings difficulties for decision-making in the public sector under limited time, resources and capitals. Due to non-professional government staff, the decision-making method of government procurement shall be scientific, reasonable and simple as much as possible to adapt to requirements on government's special preference and multilayer selection.

Secondly, government is a non-profit organization and its decision-making goal mainly focuses on public welfare. Except for limited resources, government purchasing by invitation to bid has to realize certain social goal and pay more attentions on social benefits than the economic benefits. Compared to private purchase

Copyright © Canadian Research & Development Center of Sciences and Cultures

behaviors, enterprise purchase behaviors are easier to compromise to the satisfying secondary attributes. However, the government procurement decision-making won't compromise to other attributes in requirements on social benefit and public benefit. This determines certain lexicographic preference during the investment purchase of government.

Finally, public procurement has large amount of money and the involved fields are important problems related with national economy and the people's livelihood. In some special fields, government procurement prefers some attributes to others; otherwise, it will cause serious consequences. Take the military supplier selection for example (Yang & Zhu, 2015). Government's requirements on importance of quality and reaction speed are obviously prior to other attributes. If quality and reaction speed couldn't reach certain standards, other good attributes (e.g. low price) won't be selected.

To sum up, a MCDM model applicable to fuzzy environment of lexicographic preference was proposed in this paper. Section 1 introduces government procurement problems and lexicographic preference. Section 2 constructs the decision-making model. Section 3 applies the model to the firefighting cushion bidding of a public security department.

1. BASIC DEFINITION AND BASIC MODEL

1.1 Establish the Decision Information Sheet

Attributes are the standard of supplier selection and given weights according to their importance, which is expressed by $C=\{c_1,c_2,\dots,c_n\}$. The plan is the alternative that has to be decided and ordered finally, which is expressed by $A=\{a_1,a_2,\dots,a_n\}$. The final plan in this paper refers to the supplier. The attribute value of plan a_i on the attribute c_j is x_{ij}. The proposed model mainly gets the decision-making ordering by comparing values of x_{ij} under the same attribute, thus having no requirements on measurement and type of x_{ij} in different attributes. However, different types of data have to be normalized for comparison.

Definition 1: x_{ij} refers to the bidding value of a_i under c_j. According to different characteristics of attribute values, attributes are divided into two types: criteria of benefit type and criteria of cost type.

Criteria of benefit type means that the higher attribute value, the better the plan under this attribute will be. For example, a_1 and a_2 under c_j value x_{1j} and x_{2j}. If $x_{1j} > x_{2j}$, a_1 is better than a_2, indicating that $a_1 > a_2$. The criteria of cost type mean that if $x_{1j} > x_{2j}$, a_2 is better than a_1, indicating that $a_1 < a_2$.

Different criteria of the original data have to be normalized (Liu, 1996):

For the criteria of benefit type c_j:

$$x_{ij} = \frac{y_{ij} - \min(y_j)}{\max(y_j) - \min(y_j)}, i = 1,2,\cdots,n \quad . \tag{1}$$

For the criteria of cost type c_j:

$$x_{ij} = \frac{\max(y_j) - y_{ij}}{\max(y_j) - \min(y_j)}, i = 1,2,\cdots,n \quad . \tag{2}$$

The decision-making matrix after normalization is:

$$\begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix}.$$

Definition 2: Preference function and conversion function.

Preference function:

$$P(x,y) = \frac{y-x+1}{2} \quad . \tag{3}$$

Conversion function:

$$T(x) = \begin{cases} 0, 0 \le x \le \frac{1}{2} \\ \frac{1}{2}, x = \frac{1}{2} \\ 1, \frac{1}{2} \le x \le 1 \end{cases} \quad . \tag{4}$$

1.2 Plan Comparison

Definition 3: The comparison value of the single attribute under the attribute c_k is ε^k_{ij}. The proposed decision-making model is applicable to fuzzy environment, manifested by processing of attribute values which have different measurement units and low accuracy. It makes decisions mainly by comparing decision values of different plans and won't influence the specific difference between two attribute values. This also determines that the final decision-making value of this model has the characteristic of ordinal number rather than non-ordinal number.

$$\varepsilon^k_{ij} = T\left[P\left(x_{ik}, x_{jk}\right)\right] = \begin{cases} 0, x_{ik} > x_{jk} \\ \frac{1}{2}, x_{ik} = x_{jk} \\ 1, x_{ik} < x_{jk} \end{cases}, i = 1,2,\cdots,n, j = 1,2,\cdots,m \; , \tag{5}$$

 Copyright © Canadian Research & Development Center of Sciences and Cultures

Contrast matrix of single attribute is:

$$\begin{pmatrix} \varepsilon_{11}^{k} & \cdots & \varepsilon_{1m}^{k} \\ \vdots & \ddots & \vdots \\ \varepsilon_{m1}^{k} & \cdots & \varepsilon_{mm}^{k} \end{pmatrix}.$$

It is easy to know that the diagonal value of this matrix is $\frac{1}{2}$.

1.3 Set Weights of Attributes

Definition 4: Contrast value of comprehensive attributes and comprehensive function. Contrast values of different plans under single attribute are combined through the comprehensive function, thus getting the contrast value of comprehensive attributes ε_{ij}. Different preferences have different attribute weights and comprehensive functions.

$$\varepsilon_{ij} = G\left\{\sum_{k=1}^{n} w_k T\left[P\left(x_{ik}, x_{jk}\right)\right]\right\} = G\left[\sum_{k=1}^{n} w_k \varepsilon_{ij}^{k}\right], i = 1, 2, \cdots, n, j = 1, 2, \cdots, m\,. \tag{6}$$

The nature of comprehensive function $G=G(x)$ is to make weighted evaluation of contrast values of different attributes according to their weights. The comprehensive function differs with decision-making requirements and shall be selected according to specific decision-making requirements.

The comprehensive attribute contrast matrix is:

$$\begin{pmatrix} \varepsilon_{11} & \cdots & \varepsilon_{1m} \\ \vdots & \ddots & \vdots \\ \varepsilon_{m1} & \cdots & \varepsilon_{mm} \end{pmatrix}.$$

It is easy to know that the diagonal value of this matrix is $\frac{1}{2}$.

1.4 Decision-Making Based on Acquired Comprehensive Decision Value

Definition 5: Decision value. The decision value is gained by the contrast value of comprehensive attribute and the comprehensive function. The smaller the decision value is, the better the plan will be. This is related with definitions of above contrast value and conversion function. The decision value is:

$$L_i = \frac{1}{m}\sum_{j=1}^{m} G\left\{\sum_{k=1}^{n} w_k T\left[P\left(x_{ik}, x_{jk}\right)\right]\right\} = \frac{1}{m}\sum_{j=1}^{m} \varepsilon_{ij}, i = 1, 2, \cdots, n\,. \tag{7}$$

It can be seen from above steps that the proposed decision-making model can be applied to decision analysis of various different requirements. Different decision requirements mainly are manifested on attribute empowerment and comprehensive function. This characteristic will be reflected in the application model of following two layers of basic function. As mentioned above, the gained decision value has no property of cardinal number. In other words, if the decision value of plan a_1 is 0.6 and the decision value of plan a_2 is 0.3, the later plan is better than the former one, but it doesn't mean that the later plan is twice better than the former one.

2. MULTI-EXPERT LEXICOGRAPHIC MCDM MODEL

The established multi-expert lexicographic MCDM model mainly uses above basic model twice. The first use is to combine multi-expert attributes for comprehensive ordering. The second use is to select multi-attribute plan. Weights of attributes are given according to the comprehensive attribute ordering and lexicographic preference of decision-making subject, thus getting the decision value. Specific steps are:

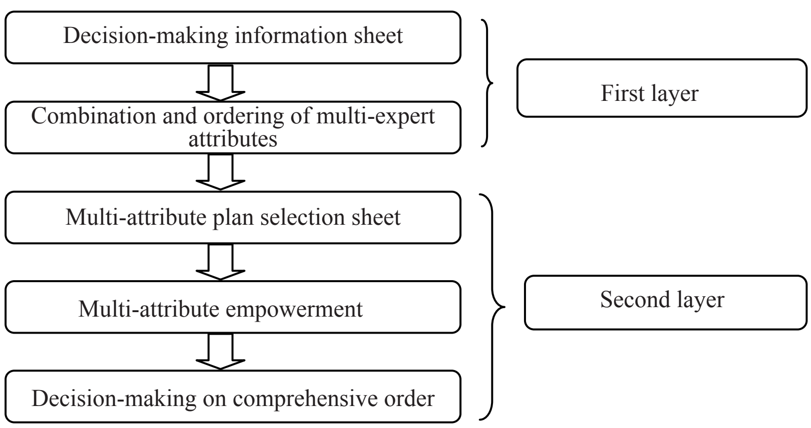

Figure 1
Multi-Expert Two-Layer DCDM Model

2.1 Establish the Decision-Making Information Sheet on Multi-Expert Opinion Combination

This is to combine multi-expert opinions and form the attribute order according to their importance. Firstly, ranking code of attribute order is given to every expert. Suppose there are S experts and the expert set is expressed as $P=\{p_1, p_2,\ldots, p_s\}$. The attribute set is $C=\{c_1,c_2,\ldots,c_n\}$. The order of the expert j to the attribute i is f_{ij} and the ranking code is O_{ij}, $O_{ij}=n-f_{ij}+1$ (this step is to change the criteria of cost type of order into the criteria of benefit type of ranking code). The primary decision-making matrix is given:

$$\begin{pmatrix} o_{11} & \cdots & o_{1s} \\ \vdots & \ddots & \vdots \\ o_{n1} & \cdots & o_{ns} \end{pmatrix}.$$

Obviously,

$$\sum_{i=1}^{n} o_{ij} = \frac{n(n+1)}{2}, j = 1,2\cdots,s . \tag{8}$$

Next, normalize the decision-making matrix (order is the criteria of cost type and ranking code is the criteria of benefit type. Normalize by two methods).

2.2 Gain Comparison of Multi-Expert Attributes Ordering

The single attribute comparison matrix can be received according to above preliminary decision-making matrix (Equation (5)). Next, weights of speaking rights of all experts (If speaking rights of all experts are same, their weights are $1/s$) shall be combined. In decision-making of public sector, weights could be given according to authority degree of experts as well as duty and title of public officials. In private departments, weights could be given according to shares. The contrast value of comprehensive attribute is gained by the comprehensive function (Equation (6)):

$$\varepsilon_{ij} = G\left\{\sum_{k=1}^{n} w_k T\left[P\left(x_{ik}, x_{jk}\right)\right]\right\} = G\left[\sum_{k=1}^{n} w_k \varepsilon_{ij}^{k}\right].$$

$$\begin{pmatrix} \varepsilon_{11}^{k} & \cdots & \varepsilon_{1n}^{k} \\ \vdots & \ddots & \vdots \\ \varepsilon_{n1}^{k} & \cdots & \varepsilon_{nn}^{k} \end{pmatrix} \quad \begin{pmatrix} \varepsilon_{11} & \cdots & \varepsilon_{1n} \\ \vdots & \ddots & \vdots \\ \varepsilon_{n1} & \cdots & \varepsilon_{nn} \end{pmatrix}.$$

Finally, attributes are ordered according to decision values (Equation (7)):

$$L_i = \frac{1}{n}\sum_{j=1}^{m} G\left\{\sum_{k=1}^{s} w_k T\left[P\left(x_{ik}, x_{jk}\right)\right]\right\} = \frac{1}{n}\sum_{k=1}^{n} \varepsilon_{ij}, i = 1,2,\cdots,n . \tag{9}$$

2.3 Establish the Decision-Making Information Sheet of Supplier Ordering

The attribute order gained from above steps is $C=\{c_1,c_2,c_n\}$, which is a descending order of importance. The plan (supplier) that has to be decided is expressed as $A=\{a_1,a_2, \ldots,a_m\}$, where x_{ij} is the attribute value of plan (supplier) a_i under the attribute c_j. Then, the decision-making matrix of the plan is:

$$\begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix}.$$

2.4 Set Attribute Weighting Plan Meeting Lexicographic Preference

The characteristic of lexicographic preference is that attributes in front of the order have absolute advantages than those in back of the order. When attributes in front of the order fail to meet requirements, the follow-up attributes couldn't compensate for bidding rate of the whole plan. If expressed by weights, weights of attributes in front of the order are higher than the sum of weights of rest attributes. Weights decrease gradually and the sum of all weights is 1. In this paper, a weighting plan of full lexicographic preference is:

$$w_i = \frac{1}{2^i} + \frac{1}{n2^n}, \sum_{i=1}^{n} w_i = 1, i = 1,2,\cdots,n . \tag{10}$$

In practical decision-making, it is rare that all attributes obey to lexicographic preference. According to decision-making goal, public decision-making pay attention to attributes oriented to public welfare and social benefits, meeting the lexicographic preference of partial attributes. The weighting plan can adjust weights of all attributes according to practical situations. In this paper, two weighting plans of previous two attributes meeting the lexicographic preference are:

$$w_i = \begin{cases} \dfrac{1}{2^i} + \dfrac{1}{n2^n}, i = 1,2 \\ \dfrac{1-\left(\dfrac{1}{2^1} + \dfrac{1}{2^2} + \dfrac{2}{n2^n}\right)}{n-2}, i = 3,4,\cdots,n \end{cases} . \tag{11}$$

Weighting plan under different preferences is different. Three weighting plans used in this paper are introduced in the following text:

 Copyright © Canadian Research & Development Center of Sciences and Cultures

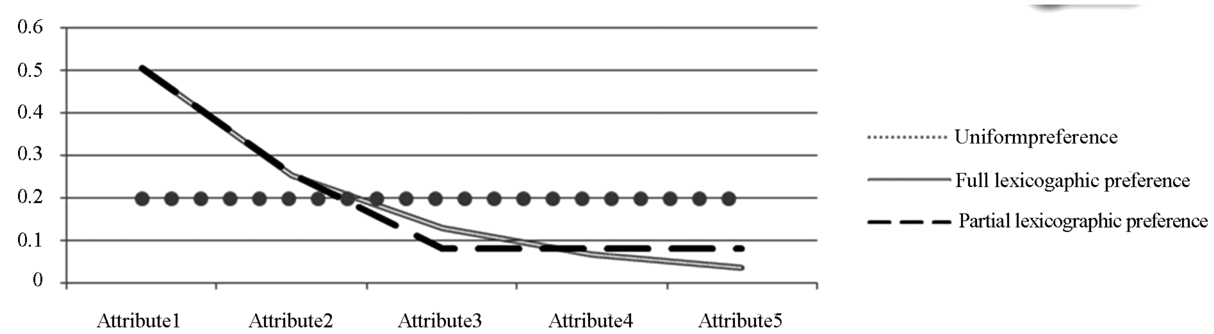

Figure 2
Three Weighting Plans of Common Preference

Considering special weights of lexicographic preference, an applicable comprehensive function was given:

$$G(x)=T(x)=\begin{cases}0, 0\le x\le\dfrac{1}{2}\\ \dfrac{1}{2}, x=\dfrac{1}{2}\\ 1, \dfrac{1}{2}\le x\le 1\end{cases}. \tag{12}$$

2.5 Gain the Comprehensive Decision Value for Decision-Making

The contrast value of comprehensive attribute and the comprehensive decision value $L=\{L_1,L_2,\ldots,L_m\}$ are gained according to Equations (6) and (7). Decision values are compared to get the plan orders.

$$\begin{pmatrix}\varepsilon_{11} & \cdots & \varepsilon_{1m}\\ \vdots & \ddots & \vdots\\ \varepsilon_{m1} & \cdots & \varepsilon_{mm}\end{pmatrix}.$$

3. MCDM MODEL FOR FIREFIGHTING CUSHION BIDDING

The proposed model was verified by the supplier selection of firefighting cushion of a public security department (data comes from the Firefighting Equipment Supplier Bidding Announcement of Shandong Public Security Department on the public procurement website of Shandong government). Technological indexes of bidding instruction are:

Table 1
Technological Indexes of Firefighting Cushion

No.	Product name	Technological indexes	Quantity
1	Firefighting cushion	1. Meet GA631 firefighting cushion. 2. Cushion has obvious blank and the rescue area≥25m^2. 3.Use cylinder air inflation and the complete air inflation time ≤90s. ★4. The maximum lifesaving height ≥16 m. 5.The safety valve provides the overpressure protection and the repeated use time ≤5s. 6. Accept import products.	1

Note. If the ★ condition doesn't satisfy, the plan is viewed as invalid bidding.

In Table 1, the government bidding document demonstrates clearly that condition 4 is the most important index. If the bidding enterprise couldn't meet the condition 4, it is viewed as invalid bidding. This conforms to the characteristic of lexicographic preference decision-making. In this paper, attributes are put in the important descending order. Therefore, the item 4 is determined as the attribute 1 and the attribute set is: c_1 is the maximum lifesaving height≥16m; c_2 is to meet GA631 Firefighting Cushion; c_3 is that the cushion has an obvious target and the rescue area is ≥25m^2; c_4 is cylinder air inflation and the complete air inflation time≤90s; c_5 is that the safety valve provides overpressure protection and the repeated use time is ≤5s. The condition 6 that accepts import product is not the limiting condition and isn't used as decision-making attribute in this case. Four experts' decision-making matrixes on five attributes are:

$$\begin{pmatrix}5 & 3 & 2 & 5\\ 1 & 5 & 5 & 3\\ 3 & 2 & 3 & 1\\ 2 & 1 & 4 & 4\\ 4 & 4 & 1 & 2\end{pmatrix}.$$

Obviously, attribute order of the expert p_1 is $c_1 > c_5 > c_3 > c_4 > c_2$ and the sum of ranking code of each column is

$$\sum_{i=1}^{n} o_{ij} = \frac{n(n+1)}{2} = 15.$$

The contrast matrix of single matrix is:

$$\begin{pmatrix} \frac{1}{2} & 0 & 0 & 0 & 0 \\ 1 & \frac{1}{2} & 1 & 1 & 1 \\ 1 & 0 & \frac{1}{2} & 0 & 1 \\ 1 & 0 & 1 & \frac{1}{2} & 1 \\ 1 & 0 & 0 & 0 & \frac{1}{2} \end{pmatrix} \begin{pmatrix} \frac{1}{2} & 1 & 0 & 0 & 1 \\ 0 & \frac{1}{2} & 0 & 0 & 0 \\ 1 & 1 & \frac{1}{2} & 0 & 1 \\ 1 & 1 & 1 & \frac{1}{2} & 1 \\ 0 & 1 & 0 & 0 & \frac{1}{2} \end{pmatrix} \begin{pmatrix} \frac{1}{2} & 1 & 1 & 1 & 0 \\ 0 & \frac{1}{2} & 0 & 0 & 0 \\ 0 & 1 & \frac{1}{2} & 1 & 0 \\ 0 & 1 & 0 & \frac{1}{2} & 0 \\ 1 & 1 & 1 & 1 & \frac{1}{2} \end{pmatrix} \begin{pmatrix} \frac{1}{2} & 0 & 0 & 0 & 0 \\ 1 & \frac{1}{2} & 0 & 1 & 0 \\ 1 & 1 & \frac{1}{2} & 1 & 1 \\ 1 & 0 & 0 & \frac{1}{2} & 0 \\ 1 & 1 & 0 & 1 & \frac{1}{2} \end{pmatrix}.$$

Attribute orders of different experts are combined to compare matrixes and weights of their speech rights. Based on the comprehensive function and contrast value of the comprehensive attribute (Equation (6))

$$\varepsilon_{ij} = G\left\{\sum_{k=1}^{n} w_k T\left[P\left(x_{ik}, x_{jk}\right)\right]\right\} = G\left[\sum_{k=1}^{n} w_k \varepsilon_{ij}^{k}\right], i = 1, 2, \cdots, n, j = 1, 2, \cdots, m,$$

the contrast matrix of the comprehensive attribute is:

$$\begin{pmatrix} \frac{1}{2} & \frac{1}{2} & \frac{1}{4} & \frac{1}{4} & \frac{1}{4} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{4} & \frac{1}{2} & \frac{1}{4} \\ \frac{3}{4} & \frac{3}{4} & \frac{1}{2} & \frac{1}{2} & \frac{3}{4} \\ \frac{3}{4} & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \\ \frac{3}{4} & \frac{3}{4} & \frac{1}{4} & \frac{1}{2} & \frac{1}{2} \end{pmatrix}.$$

Then, the decision value is gained (Equation (9)):

$$L_1 = \frac{1}{5}\left(\frac{1}{2}+\frac{1}{2}+\frac{1}{4}+\frac{1}{4}+\frac{1}{4}\right) = \frac{7}{20},$$

$$L_2 = \frac{1}{5}\left(\frac{1}{2}+\frac{1}{2}+\frac{1}{4}+\frac{1}{2}+\frac{1}{4}\right) = \frac{2}{5},$$

$$L_3 = \frac{1}{5}\left(\frac{3}{4}+\frac{3}{4}+\frac{1}{2}+\frac{1}{2}+\frac{3}{4}\right) = \frac{13}{20},$$

$$L_4 = \frac{1}{5}\left(\frac{3}{4}+\frac{1}{2}+\frac{1}{2}+\frac{1}{2}+\frac{1}{2}\right) = \frac{11}{20},$$

$$L_5 = \frac{1}{5}\left(\frac{3}{4}+\frac{3}{4}+\frac{1}{4}+\frac{1}{2}+\frac{1}{2}\right) = \frac{11}{20}.$$

Attribute order could be gained according to above decision values: $c_1 > c_2 > c_4 = c_5 > c_3$, which reflects that the importance descending order of five attributes is: maximum lifesaving height≥16m; meet GA631 Firefighting Cushion; cylinder air inflation and the complete air inflation time≤90s; safety valve provides overpressure protection and the repeated use time is ≤5s; the cushion has an obvious target and the rescue area is ≥25m^2.

Let $c_1=C_1, c_2=C_2, c_4=C_3, c_5=C_4 c_3=C_5$. The re-ordered attributes are $C=\{c_1,c_2,\ldots,c_5\}$, whose importance decreases gradually. The plans (suppliers) are $A=\{a_1,a_2,\ldots,a_5\}$. Samples provided by suppliers are recorded according to experts' opinions and the following data are acquired:

Table 2
Decision-Making Information Sheet of Supplier Selection

	C_1	C_2	C_3	C_4	C_5
a_1	15	5	5	8	53
a_2	18	5	3	15	55
a_3	16	7	7	5	54
a_4	13	6	10	10	53
a_5	18	7	3	10	53

The normalized decision-making matrix is:

$$\begin{pmatrix} 0.4 & 0 & 0.3 & 0.3 & 0 \\ 1 & 0 & 0 & 1 & 1 \\ 0.6 & 1 & 0.6 & 0 & 0.5 \\ 0 & 0.5 & 1 & 0.5 & 0 \\ 1 & 1 & 0 & 0.5 & 0 \end{pmatrix}.$$

This firefighting cushion selection conforms to lexicographic preference and the weighting plan of attributes is $w_i = \frac{1}{2^i} + \frac{1}{n2^n}, \sum_{i=1}^{n} w_i = 1, i = 1, 2, \cdots, n$.

Since $c_3=c_4$, let $w_3 = w_4 = \frac{1}{2}\left(\frac{1}{2^3}+\frac{1}{2^4}+\frac{2}{n2^n}\right) = \frac{1}{10}$.

Finally, the contrast matrix of the comprehensive attribute

 Copyright © Canadian Research & Development Center of Sciences and Cultures

and comprehensive decision value of plan ordering are gained (Equation (7)):

$$\begin{pmatrix} \frac{1}{2} & 1 & 1 & 0 & 1 \\ 0 & \frac{1}{2} & 0 & 0 & 1 \\ 0 & 1 & \frac{1}{2} & 0 & 1 \\ 1 & 1 & 1 & \frac{1}{2} & 1 \\ 0 & 0 & 0 & 0 & \frac{1}{2} \end{pmatrix},$$

$$L_1 = \frac{7}{10}, L_2 = \frac{3}{10}, L_3 = \frac{5}{10}, L_4 = \frac{9}{10}, L_5 = \frac{1}{10}.$$

Therefore, the plan order is $a_5 > a_2 > a_3 > a_1 > a_4$ and the plan (supplier) a_5 is the final enterprise that wins the bidding.

CONCLUSION

In decision-making of government procurement, decision-making that considers single attribute (e.g. cost and bidding price) couldn't adapt to detailed, accurate and high-efficient requirements of government procurement. With the increasing requirements on reasonableness and scientificity of government decision-making, how to make scientific and effective decision-making under limited resources and time with considerations to cost efficiency and public welfare as well as social benefits of government decision-making has attracted attentions of the government. Therefore, MCMD based on democratic systems like multi-expert hearing system is the inevitable trend of government procurement in the future.

First, the decision-making plan which uses contrast matrix is extracted into a widely applied model by the induction method. This model reflects different decision-making requirements through weights of attribute variables and changes of the comprehensive function. Then, based on the simplified model, this model is used twice in multi-expert MCMD problem by the deduction approach. The proposed decision-making model mainly has following characteristics:

(a) It reflects lexicographic preference of government procurement decision-making. Different from previous behavior that pays attentions to the construction of government procurement index (attribute) system, this paper emphasizes on index (attribute) ordering and plan selection after the index (attribute) system is established. In the firefighting cushion purchase case, the attribute value of plan (supplier) 2 and plan (supplier) 5 under the attribute c_1 are same (18, 18). The attribute values of plan 2 under the attributes $c_3c_4c_5$ (3, 15, 55) are no lower than those of plan 5, but plan 2 fails in the bidding due to the small value of the attribute c_2 (5, 7). Results show that the total ordering could be gained basically as long as the lexicographic preference decision-making under five attributes and five suppliers compares c_1. Given same attribute values under the attribute c_1, the attribute values under the attribute c_2 shall be further compared. In other words, only the attributes c_1 and c_2 influences the final ordering of plan, indicating that the chosen important indexes have received adequate attentions.

(b) It reflects diversity and non-technological property of government procurement. In government procurement, previous models are difficult to be used, which is attributed to non-professional officials. In the firefighting purchase case, attribute orders of different experts are compared pairwise. When these orders are combined according to speaking rights of experts, we find that given the same speaking rights of experts, the proposed model has same results with ordinary weighted average results. In other words, when opinions of multiple experts are combined, if all experts have consistent weights, weighted average of all experts' orders under single attribute could be carried out directly as long as attribute values are compared. However, common weighted average method is not applicable when experts have different speaking rights. The proposed model can make decisions by changing the weighting plan. Therefore, a simple model that can meet different weighting plans is put forward in this paper. It is applicable to diversify government procurement decision-making and avoids technological difficulties of complicated model.

REFERENCES

Almeida, A. T. (2007). Multicriteria decision model for outsourcing contracts selectiong based on utility function and ELECTRE method. *Computers & Operations Reseach, 34*(35), 69-74.

Brans, J. P., & Vincke, P. H. (1985). A preference ranking organization method. *Management Science, 31*(6), 47-56.

Isiklar, G., & Buyukozkan, G. (2007). Using a multi-criteria decision making approach to evaluate mobile phone alternatives. *Computer Standards & Interfaces, 29*(2), 65-74.

Jozsef, D., & Nandor, V. (2005). The lexicographic decision function. *Acta Cybernetica, 17*(5), 95-106.

Lin, Y., & Ma, S. H. (2000) Research on supplier's comprehensive evaluation and selection in supply chain management environment. *Logistics Technology, 16*(5), 30-32.

Liu, X. J. (1996). Discussion on the analytic hierarchy process of quantitative multi criteria decision making. Operations *Research and Management Science, 53*(3), 10-15.

Copyright © Canadian Research & Development Center of Sciences and Cultures

Lou, P., & Chen, Y. P. (2002). AHP/DEA method for supplier selection in agile supply chain. *Journal of Huazhong University of Science and Technology (Natural Science Edition),* (4), 29-31.

Nicola, C., Mariagrazia, D., & Falagaria, M., et al. (2011). Using fuzzy decision making for supplier selection in public procurement. *Journal of Public Procurement, 11*(3), 403-427.

Nydick, L., & Hill, R. P. (1992). Using the analytic hierarchy process to structure the supplier selection procedure. *International Journal of Purchasing and Materials Management,* (35), 31-36.

Roodhooft, F., & Jozef, K. (1996)Vendor selection and evaluation an activity based costing approach. *European Journal of Operational Research,* (96), 97-102.

Yang, L. (2007). Multi index group decision-making method under incomplete information. *System Engineering-Theory & Practice, 5*(3), 172-176.

Yang, L., Zhu, Y. Q., & Liao, G. J. (2015). Selection method of military materials suppliers based on lexicographic preference. *Journal of System Engineering and Electronics, 37*(04), 827-830.

Zeger, D., Labro, E., Roodhooft, F. (2000). An evaluation of vendor selectiong models from a total cost of ownership perspective. *European Journal of Operational Reseach, 14*(125), 34-58.

Zhang, J., Dong, C., Wu, X. Y. (2001). Using AHP and LP to solve the problem of supplier selection. *China Business and Market, 9*(l), 28-34.

Copyright © Canadian Research & Development Center of Sciences and Cultures